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INTERRELATIONS OF THE FOSSIL FUELS.*

III.

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THE JURASSIC AND TRIASSIC COALS.

THE JURASSIC.

Like the Cretaceous, this is barren in the greater part of its extent within Europe and the productive areas are of limited extent, though some of them are important. Conditions favoring accumulation of coal existed in widely separated localities elsewhere, as in Siberia, Australia, New Zealand and Alaska; in some of which the deposits may prove to be valuable. The geologic features have material bearing upon the problem under consideration in this study.

Great Britain.—British geologists have grouped the Jurassic deposits into Upper, Middle, Lower Oölite and the Lias. Transition from the Cretaceous is often gradual. Local deposits of coal are in the Lower Oölite and soils of vegetation have been observed in both the Upper and the Lower Oölite.

The Purbeck "Dirt Beds," soils of vegetation near top of the Upper Oölite, have been mentioned in most of the text-books on

* Part I. appeared in these *Proceedings*, Vol. LV., pp. 21-203; Part II., in Vol. LVI., pp. 53-151.

geology. They were described first by Webster, then by Buckland and de la Beche and still later by Mantell.¹ The chief "Dirt Bed" with erect stumps was recognized by all as a black loam with remains of tropical plants, which accumulated where they grew. This soil, about one foot thick, contains slightly rounded fragments of stone and, as Webster showed, is the original matrix of the silicified stems; for, wherever exposed, it contains trunks of coniferous trees, partly in the black earth and partly surrounded by the overlying calcareo-silicious strata. The intervals are very nearly the same as those seen in recent forests and the erect stumps or stools of the large trees with attached roots are in their original soil. Associated with the coniferous stems are others of cycad-like plants, also silicified. The same condition was observed at another locality, where the dip is 45 degrees and the stems are vertical to the plane of bedding.

Mantell states that the "Dirt Bed" has a considerable quantity of lignite and of waterworn pebbles. While the prevailing trees are conifers, there is abundance of plants allied to *Zamia* and *Cycas*. Many of the trees are erect, as if petrified during growth. The roots are in the black clay, and the stems reach into the overlying calcareous rocks. Just prior to Mantell's visit, a large area of the "Dirt Bed" has been exposed preparatory to removal that the underlying rock might be quarried. Some of the trunks were surrounded by calcareous earth; the upright stems were only a few feet apart and usually were not more than 3 or 4 feet high; without exception they are splintered at the top as though they had been wrenched or snapped off. All are without bark and have a weather-worn surface, resembling that of posts set between tides. Two other dirt beds were examined by Mantell, who obtained cycads from both: the principal bed is so little consolidated that he was able to dig out several cycads and to prove that they are actually *in situ*.

¹ T. Webster, "Observations on the Purbeck and Portland Beds," *Trans. Geol. Soc.*, II., Vol. 2, 1829, pp. 41, 42; W. Buckland and H. T. de la Beche, "On the Geology of the Neighborhood of Weymouth, etc.," the same, Vol. 4, 1836, pp. 13-15; G. A. Mantell, "Geological Excursions around the Isle of Wight," 3d ed., 1854, pp. 286-290.

The conditions described by Mantell recall those seen by Russell² on the Yahtse of Alaska. That stream, issuing as a swift current from beneath a glacier, invaded a forest area and surrounded the trees with sand and gravel. Some stems, still retaining their branches, projected above the mass but most of the decaying trunks had been broken off by the wind and entombed in prostrate position. The phenomenon is familiar to all who have travelled along rivers with broad bottoms. Lyell states that the top beds of the Portlandian or middle division of the Upper Oölite, containing marine shells, were covered with fluvial muds on which *Zamia* and cycads grew.³ He remarks that each dirt bed may represent a notable period of time; 2 to 3 feet of vegetable soil is the only product of very old tropical forests.

The Kimmeridge Clay, at base of the Upper Oölite, contains, according to Phillips,⁴ a highly bituminous shale, which is utilized as fuel at Kimmeridge on the Purbeck coast. As shown in cliffs near that place, the clay, finely laminated and grayish-yellow, with remains of plants and animals, passes gradually into a bituminous shale, which is dark brown, lusterless, slightly calcareous and burns with a smoky flame. Lyell⁵ states that this sometimes becomes an impure coal and that in Wiltshire it resembles peat. Plant remains are rare and the bitumen may be due, at least in part, to animal matter.

The coal at Brora in Scotland belongs to the Great Oölite or highest division of the Lower Oölite, which in that region is a mass of sandstones and shales. The seams at Brora are thin, but one of them was worked many years ago for local use. This petty area was described by Murchison, whose measurements are (1) fossil shells, marine, quartz grains, carbonaceous matter, all cemented by calcareous material, passing downward into a mass of compressed leaves and stems, in turn becoming shaly coal, 2 feet, 7 inches; (2) coal resembling jet, divided midway by a parting of pyritous, in-

² I. C. Russell, "Second Expedition to Mount St. Elias," 13th Ann. Rep. U. S. Geol. Survey, 1893, Part I., p. 14, Pl. XII.

³ C. Lyell, "Elements of Geology," 6th ed., New York, 1866, pp. 391-393.

⁴ J. Phillips, "Outlines of Geology of England and Wales," Part I., 1822, pp. 127, 128.

⁵ C. Lyell, "Elements," p. 394.

durated clay; in burning it gives off the characteristic odor of imperfect coal; the powder is brown, 3 feet, 3 inches to 3 feet, 6 inches. This is one of the few localities in Britain where coal is present in workable thickness, but the coal is inferior and no longer of even local importance. Miller⁶ has given some notes concerning the Oölite conglomerate of Eigg, one of the Hebrides. The Scur of Eigg is described as a mass of igneous rock resting on a pile foundation, composed of pine stems, laid crosswise. These stems of *Pinites eiggensis* are transported material; they are so numerous near Helmsdale that the people collect them and burn them into lime. The tree was as abundant on the mainland of Scotland as the Scotch fir is at present. It was of slow growth but attained gigantic size. Witham's study of the structure proved it very different from that of the Carboniferous conifers. The wood abounds in turpentine vessels or lacunæ of varying size, which are well defined, the minutest detail of structure being distinct. Occasionally Miller found a thin streak of brilliant lignite, resembling that of Brora, but in every case it was only the bark of a tree.

The Lower Oölite in Lincolnshire, according to Morris,⁷ has soils of vegetation with well-defined underclays. In one section, bituminous clay, 18 inches thick, rests on "gray clay with vertical stems and roots descending from the overlying bed." Another section shows the bituminous band only 6 inches thick with 7 feet of underclays containing vertical stems. At Dane's Hill the root-bed is only 9 inches, but at Aunby Cutting, he saw two bituminous clays, of which the upper contains lignite and impure coal. Each has its root-bed below.

The Inferior Oölite, at base of the Lower Oölite, has some coal in Yorkshire. Phillips⁸ recognized two groups of sandstones and shales along the coast. The lower consists of white to yellow sandstones and shales, with irregular seams of bad coal; the plants are cycads and ferns but equisetiform remains are in the upper layers, standing vertically as if in place of growth. A thin irregular seam

⁶ H. Miller, "The Cruise of the *Betsy*," Boston, 1862, pp. 51-55, 71.

⁷ J. Morris, "On Some Sections in the Oölitic District of Lincolnshire," *Quart. Jour. Geol. Soc.*, Vol. 9, 1853, pp. 326-331.

⁸ J. Phillips, "Geology of Yorkshire," 2d ed., London, 1835, Part I., pp. 8-10, 65, 66, 173, 174.

of coal near the top has been mined at some places. The higher group contains thin irregular coal seams; one, 8 inches thick, rests on 4 feet of grit holding carbonaceous markings and at 80 feet lower a white sandstone, associated with coal, has similar "coal pipes." Coal seams are present throughout northeastern Yorkshire and occasionally become thick enough for mining, but the coal is not good. The flora consists preëminently of ferns, but cycads and conifers are abundant.

Fox-Strangways and Barrow⁹ have given additional details respecting the east coast of Yorkshire. A section on Gresthope Bay, where the Middle Estuarine Series of the Lower Oölite consists of thin-bedded sandstones and shales, shows (1) black coaly shale, 0 feet, 3 inches; (2) soft, white sandstone with rootlets, 1 foot; (3) gray shale, 5 feet; (4) sandstone and shale, 3 feet, 6 inches; (5) black shale, 1 foot, 6 inches; (6) fine laminated sandstone, 1 foot, 6 inches; (7) fine laminated shale, 6 feet; (8) false-bedded sandstone, with irregular patches of coal, plants, pyrite and carbonized wood, 21 feet. The last rests on the Millepore Series, in which rippled sandy shales occur; the impure coal at top of the section rests on the sandy floor into which the plants thrust their roots.

The Lower Estuarine series is exposed at many places between Whitby and Scarborough, where it underlies the Millepore Series. A section at Blea Wyke shows a thin coal seam roofed by 30 feet of dark shale and resting on 2 feet of underclay, below which is ferruginous sandstone, 12 feet, containing great numbers of erect stems, allied to *Equisetites* and often 5 feet high. Two other seams, 2 and 3 inches thick and separated by 2 feet of soft sandstone, are at 18 feet below the top seam. The lower one rests on 6 feet of dark shale overlying 24 feet of false-bedded sandstone. In the Hawsker District, a coal seam, 4 inches, is at only 3 feet above the Dogger and the intervening shale contains roots. The Dogger in this district has vertical stems of *Equisetites*. The Middle Estua-

⁹ C. Fox-Strangways, "The Geology of the Oölitic and Cretaceous Rocks South of Scarborough," Mem. Geol. Surv., 1880, p. 5; "The Geology of the Oölitic and Liassic Rocks to the North and West of Malton," Memoirs, 1881, p. 8; the same and G. Barrow, "The Geology of the Country between Whitby and Scarborough," 1882, pp. 31, 32.

rine Shale Series at Cloughton Wyke has vertical *Equisetites* in sandy shale and, at base, a false-bedded sandstone as in the area south from Scarborough.

Judd¹⁰ has given the section of a pit at Ufford, Northampton, in the Lower Estuarine sands, which shows a thin seam of lignite, below which are 3 feet of purplish clay and 3 feet of sand, both of which contain plant remains in vertical position; he considers that the manner of occurrence indicates that the plants are *in situ*, and that they were embedded by quiet deposition as they stood. Kendall¹¹ states as result of study of clays along the Yorkshire coast, that every coal seam examined by him rests on a root bed.

The resemblance of the Estuarine Series to the Carboniferous Coal Measures has been emphasized by several observers; the resemblance to those of the Cretaceous is equally marked. The deposits were laid down in shallow water at many horizons within the Oölite. Ramsay¹² and his associates observed that, in their district, there is much false-bedding in both the Great and the Inferior Oölite as well as in the Forest Marble, which has many fragmentary fossils in its sandy layers. Even the deposits containing marine forms frequently give evidence of deposition in shallow water. Scrope¹³ reported that many layers of the Forest Marble Beds (Great Oölite) in the neighborhood of Bath are rippled and that they show impressed footprints of various types. Those layers contain rolled fragments of shells, corals, echini, etc., and exhibit the characteristic features of a shore deposit. According to Lyell, rippled bands of Oölite are known in broad areas and are utilized for roofing.

The Lias of England is without coal, though at some localities jetified wood is abundant. The soils of vegetation in Yorkshire were described by Conybeare and Phillips:¹⁴ Conybeare stated that

¹⁰ J. W. Judd, "The Geology of Rutland," Mem. Geol. Survey, 1875, pp. 104, 105.

¹¹ P. F. Kendall, in letter of May 27, 1917.

¹² A. C. Ramsay, W. T. Aveline, E. Hull, "Geology of Parts of Wiltshire and Gloucestershire," Mem. Geol. Survey, 1858, pp. 10, 12, 14.

¹³ G. P. Scrope, "On the Rippled Markings of the Forest Marble Beds," *Proc. Geol. Soc.*, Vol. 1, 1834, p. 317.

¹⁴ W. D. Conybeare, "Outlines of the Geology of England and Wales," 1822, p. 272; J. Phillips, "Geology of Yorkshire," 1835, p. 66.

gigantic reeds are in the cliffs near High Whitby. They appear to have been rooted in a bed of shale or slate-clay and their remains protrude into a sandstone, 5 feet thick. Those which are erect retain their shape, but prostrate stems are compressed. The tops seem to have been broken off and the woody matter has disappeared, there being only sandstone casts. Phillips gave more of detail. He reports that a Lias sandstone near Whitby contains great numbers of cylindrical plants like *Equiseta*, which are erect. They were broken off above and in some cases do not reach to the top of the bed. They are broken off below but commonly pass to the lower surface of the bed and, at times, the lower joints reach into the underlying shale. The conditions have led some to regard these plants as *in situ*, but Phillips prefers to believe that they were floated down and that they were kept vertical by the weight of their roots. The writer is compelled to dissent from this explanation. If the trees had been floated down stream, they would not remain vertical, even though it be conceded that the weight of their roots would keep them vertical while floating. As soon as the roots had touched bottom, the current, gentle or strong, would push the stem down stream. "Snags," only too familiar in our western rivers, invariably point down stream. Grand' Eury was able to determine the direction of currents in St. Etienne coal basin by means of "snags" enclosed in the sandstones. Murchison,¹⁵ in a brief note referring to the observations by Phillips, stated that he had discovered another locality at the same horizon, but 40 miles away and well inland. At both localities, the stems of *Equisetum columnare* are in the normal position and appear to be rooted in the black shale. The only fossil accompanying these plants is a fresh-water bivalve.

France.—The Jurassic deposits of France contain some thin seams of coal, which rarely have more than local importance. de Serres¹⁶ reported upon the coals of Aveyron, belonging to the Lower Oölite. The mines are on the plateau of Larzac within an area of

¹⁵ R. I. Murchison, "On the Occurrence of Stems of Fossil Plants in Vertical Position, etc.," *Proc. Geol. Soc.*, Vol. 1, 1834, p. 391.

¹⁶ M. de Serres, "Des houilles sèches ou stipites des terrains jurassiques, etc.," *Bull. Soc. Geol. France*, t. 16, 1859, pp. 97-99, 104, 105.

not more than 60 by 200 kilometers. The only workable seam is extremely variable. The greatest thickness is in the group of mines known as Nuejols, where the seam is 70 to 80 centimeters. The center of the area is on the summit of the plateau, where, in two mines, the thickness is but 45 centimeters. The decrease continues toward the north, there being only 12 to 15 centimeters at 10 kilometers north from La Cavalerie. The lower part of the coal group is largely calcareous and the limestones have both marine and freshwater forms. The coal rests directly on black shale; the roof is similar but more carbonaceous and, at times, has a wood-like structure; it is at most 12 centimeters thick and is combustible. The coal yields a very fair coke with imperfect metallic luster. The lenticular form of the seam is distinct, for the thickness decreases in all directions from La Cavalerie.

Austria.—The Jurassic coals of Upper Austria belong to the Grestener beds at the base of the Lias. They have been described by Lipold¹⁷ and his associates. Hertle, in his notes upon the mining area of Bernreuth on the eastern side of this region, states that Czjžek's profile shows a marine limestone between two coal seams, which contains *Mytilus*, *Pleuromya* and *Pecten*, and a sandy shale in the same section has *Ammonites*. Sphaerosiderite concretions as large as half a cubic foot are fossiliferous. These calcareous deposits were not exposed at the time when Hertle made his examination, but he saw a sandy shale with *Pholadomya* and *Mytilus*. The coal seam, which is mined, is 3 feet thick and rests on an underclay containing remains of plants. The coal looks like good coal but it has 42 per cent. of ash.

Near Gresten, according to Rachoy, the coal seams are in a sandstone group. One tunnel cut seven streaks of coal, one to 12 inches thick, while a shaft passed through 16 seams, 3 inches to 3 feet thick. The roof and floor are sometimes clay and sometimes sandstone. The thickest bed yielded a good caking coal with less than 4 per cent. of ash; the dip is about 20 degrees. Plant remains are poorly preserved but marine fossils occur in fine condition. At

¹⁷ M. V. Lipold, G. v. Sternbach, J. Rachoy and L. Hertle, "Das Kohlengebiet in den nordlichen Alpen," *Jahrb. k. k. Geol. Reichsanst.*, Band 15, 1865, pp. 29-61.

Hinterholz, Rachoy found dips of 40 to 60 degrees and one seam, 4 feet 6 inches thick, was mined. The coal yielded 66.3 per cent. of high-grade coke, used in iron-making.

v. Sternbach's section near Grossau is (1) shale, 6 inches; (2) coal and shale, 1 foot; (3) clay shale, 1 foot; (4) coal, 3 feet; (5) shale, 6 inches; (6) sandstone, 6 feet; (7) carbonaceous shale, 6 inches; (8) coal, 6 inches; (9) carbonaceous shale, 6 inches; (10) sandstone, 1 foot; (11) shale, not measured. This, like many others, closely resembles typical short sections in Cretaceous and Carboniferous coal measures. The workable seam, Number 4, has lenses of shale, so that not more than three fourths of the output is clean coal. The roof is black shale but the floor is fine to coarse sandstone. The dip is from 55 to 60 degrees and the coal seams are extremely variable; but the variations seem to be due only in part to serious disturbance. In the Pechgraben area, v. Sternbach saw 6 well-defined coal seams as well as numerous streaks of coal in the great Franz-Stollen, where the dip is 40 to 50 degrees and the rocks as well as the coal are much shattered. The sandstones have been broken into great wedges, which interlock with similar wedges of shale. The coal seams are thin and often are distorted; but they show variations, which clearly are not due to disturbance of the stratification. The third seam, where first opened at the outcrop, consisted of numerous streaks, one to 3 inches thick; it was prospected for a considerable distance in the hope that these streaks would unite; eventually the mass became 4 feet thick but about one half of the shale still remained. The sixth seam is 9 feet thick in the tunnel, where it has 5 clay partings, in all 3 feet. But this seam, resting on shale with plant remains, is variable; in another tunnel the thickest seam is only 16 inches, while in another it is from 3 inches to 2 feet. One cannot determine in the strongly disturbed area whether the seams are lenticular or not, but there are considerable areas, in which according to the diagrams, there was little disturbance and the succession is normal; in these the lens-form is distinct. The coal is somewhat inferior, having 17.2 per cent. of ash. This Pechgraben coal, according to v. Gumbel,¹⁸ shows woody

¹⁸ C. W. v. Gumbel, "Beiträge, etc.," 1881, p. 160.

structure distinctly after treatment with Schultze's solution; even the minute details can be recognized.

The whole region of the Lias, except locally, is much disturbed, dips of 80 degrees being by no means rare, but the coal throughout contains a high percentage of volatile combustible matter and yields a strong coke. The Grestener deposits are very largely sandstone. No freshwater fossils were noted by any of the observers but there is abundant evidence of repeated invasions by the sea; the marine mollusks belong to off-shore types.

Hungary.—The importance of Liassic coals in Austria, where land conditions became pronounced, prepares one for the great development farther east in Hungary. The coal-bearing formation belongs to the Lower Lias and, according to Hantken,¹⁹ the coals are as important to Hungary as the Carboniferous coals are to England, Belgium, France and Germany, the seams being thick and the coal good. There are five important districts: Doman-Resicza, Steierdorf-Anina, Berszaszka, Fünfkirchen-Uralja and Neustadt-Törzburg; the first three are in the Krassoer Comitatie between 39 and 40 degrees of Longitude and between 44 and 45 degrees of North Latitude and are near the Serbian border; the fourth is near the 36th meridian and the 46th parallel, while the fifth is in Transylvania, close to the border of Roumania.

In the Doman-Resicza district the Lias rests on deposits of Dyas age and the dip is from 30 to 90 degrees, at times overturned. Two seams, 40 meters apart, are intercalated in the sandstone mass. The thickness of each is from nothing to nearly 3 meters and the variation is as marked along the strike as along the dip. Each has clay as floor and roof, so that the coal is apt to be dirty.

The Lias sandstone in the Steierdorf-Anina district rests on Dyas. It is 160 meters thick, light in color, is almost clean quartz sand with some mica and little clay or cementing material. There is about 10 meters of other rock, including the coal seams. These thicknesses, according to Hantken, are averages only, for all portions of the section, especially the coal seams, are variable. Eleven coal horizons were seen, of which 5 have workable seams, one to 4

¹⁹ M. Hantken, "Die Kohlenflötze, etc., der Ungarischen Krone," Budapest, 1878, pp. 44-118.

meters thick. Immediately above the lowest seam is a laminated sandstone, carbonaceous and containing many plants of swamp types. The upper part of this sandstone, floor to the second seam, is somewhat argillaceous and holds vertical plant remains resembling roots. The coal seams consist ordinarily of several benches, some of them good, but others worthless. Kudernatch's section at one locality shows (1) upper bench, clean coal, 0.713; (2) earthy, impure coal, a mixture of Faser and bright coal, locally known as "Brand," 0.552; (3) middle bench, clean coal, 1.025; (4) coal and shaly coal, 0.053; (5) lower bench, clean coal, 1.394; (6) impure coal, not mined, has steel-like luster, 0.154; total, 3.891 meters. The coal is in bright and dull laminæ, but the bright predominates. The Hangendflötz also has the Stahlband as faux-mur. The roof and floor of all the seams are shaly sandstone with remains of plants. In the lower coal group, ferns predominate, in the upper group, cycads are abundant. These groups are separated by 97 meters of barren measures and Hantken is inclined to regard the upper one as belonging to the Middle Lias. About 74 meters of bituminous shale overlies the sandstone mass and contains streaks of coal as well as layers of iron ore. Some portions of this shale yield 3 to 7 per cent. of crude oil, from which paraffin and illuminating oil are obtained. The Liassic in this district is apparently of freshwater origin; the variations in thickness of the coal seams are due in very small part to compression, as is evident from the many illustrations given by the author.

Grand'Eury, in the memoir already cited, states that the coals at Anina and Bregeda rest on soils of vegetation. At Bregeda, where the coal is anthracitic, the mur and partings have many roots in place, some of them spreading out under the coal and much divided, while others are erect and cross several layers of the shale. At Anina, where the coal is fat, woody roots are in the mur and herbaceous roots in the partings.

The greatest thickness of coal is in the small area near Fünfkirchen, where the coal group, consisting of alternating sandstones, marly shales, clay shale, coal seams and layers of iron ore, rests on Rhaetic beds and underlies the marine Middle Lias. It is about 800 meters thick. Not less than 180 coal horizons have been recognized,

with 25 to 28 workable seams. The thicknesses vary greatly and, at times, the rapid increase of earthy matter renders an important seam worthless. Mining operations are extensive and the horizons have been correlated closely. The succession of the thicker seams from below upward is

- I. and II., 24 to 36 inches, mostly unworkable ;
- III., IV., VI., 36 to 48 inches, one half to three fourths good coal ;
- VII., VIII., IX., 24 to 30 inches, occasionally too thin for working ;
- X., 18 to 24 inches, a hard coal ;
- XIII. to XIX., 12 to 24 inches, light, caking coal ;
- XX., 20 to 60 inches, coal similar to the last ;
- XXII., 0 to 60 inches, often absent ;
- XXIV. to XXVIII., 20 to 24 inches, coal is hard.

Almost the whole of the formation was crossed in the tunnel at Vasas, where 174 seams were crossed in 717 meters. The total thickness of coal is 52 meters, but one half of it is unavailable because the seams are too thin or the coal is impure. 39 seams, with thickness of somewhat more than 14 meters, are marked as containing dirty coal.

The mining districts are Fünfkirchen, Szabolcs and Vasas. In the Fünfkirchen district, dips are 30 to 50 degrees and seams less than one foot are rarely mined ; those of more than 2 feet are usually divided by partings. The mass, numbered XI. and XII. in the Vasas tunnel, consists of (1) clean coal, 0.40 ; (2) shale, 0.25 ; (3) clean coal, 0.40 ; (4) carbonaceous shale, 0.45 ; (5) clean coal, 0.48 ; (6) carbonaceous shale, 0.05 ; (7) clean coal, 0.25 ; (8) carbonaceous shale, 0.20 ; (9) clean coal, 1.00 ; (10) dirty coal, 0.60 ; (11) clean coal, 0.60 ; (12) shale, 0.05 ; (13) clean coal, 0.40 ; (14) carbonaceous shale, 0.20, resting on sandstone. The roof is shale containing mullusks. Other seams are double or triple and the partings are clay or carbonaceous shale. Of the 512 beds of rock cut by the Vasas tunnel, 8 contain marine fossils ; three of them being in the highest portion, 70 meters, a transition to the overlying *Gryphæa* beds. Many marine mollusks have been obtained from the roof of coal III., the floor of XVIII. and the partings of XIII. and XXII. These are *Ostrea*, *Gervillia*, *Panopæa*, *Lima* and other off-shore

genera. Faux-mur and faux-toit are common. The dip is high and the coal is tender; of that mined at Fünfkirchen, only one per cent. is lump, pieces as large as a man's head; 20 per cent. is coarse, 20 millimeters or larger, while the remaining 70 per cent. is "dust"; volatile in this district is about 18, but in the Szabolcs district it is about 23. The coal is black, tender and in great part caking. The gas is low in illuminants.

The flora of Fünfkirchen consists of ferns, cycads and lycopods, some of which seem to persist throughout the Lower Lias. Leaf-bearing beds seldom overlie coal seams.

In the western part of the southern area, that of Neustadt-Törzburg, the coal-bearing Lias rests on crystalline schists and consists of brown, argillaceous, micaceous sandstone, which, through increasing content of plant remains, becomes darker and finally passes into carbonaceous shale, containing streaks of coal. The roof is a quartzose sandstone without trace of plants. In the eastern division, the schists are not reached and the coal group, consisting of sandstones, marls and coal seams, rests conformably on limestones. There seems to be but one coal seam, one to 2 meters thick, but the region is so broken by folding and faulting that a detailed section cannot be obtained.

Hantken called attention in the first edition of his work to the presence of roots in the floor of coal in the Steierdorf region; Zincken,²⁰ soon afterward, noted that near Kola, in the Steierdorf district the same horizon yields abundance of roots in vertical position. Gothan,²¹ having seen the root-bearing underclays associated with Jurassic coal seams on the Yorkshire coast of England, thought wholly probable that similar clays might be present in the Fünfkirchen area. His examination was successful though, owing to physical conditions, it covered only a portion of the district. At one locality, he found under coal VII. a characteristic underclay with irregular branching coaly markings, varying in direction and

²⁰ C. F. Zincken, "Ergänzungen zu die Physiographie der Braunkohle," Leipzig, 1878, p. 159.

²¹ W. Gothan, "Untersuchungen über die Entstehung der Lias-Steinkohlenflötze bei Fünfkirchen (Pecs), Ungarn," *Sitz. k. preuss. Akad.*, VIII, 1910, pp. 129-143.

wholly resembling roots. At another, he discovered a rhizome with its rootlets, which made the relations of the other markings clear. "Through such horizontal rhizomes, the analogy of the Mesozoic underclay with the Carboniferous *Stigmaria*-beds and the recent or sub-recent reed beds is the more marked." Roots are rarely recognizable in freshly exposed rock but they are sufficiently distinct after slight weathering. Gothan removed the débris for some meters at several horizons and in one day he found well-marked underclays with roots, associated with 8 coal seams. In all, he uncovered such clays under 12 seams.

Spitzbergen.—Nathorst²² has described a sandstone group midway in his Jurassic of Spitzbergen. It contains coal seams and freshwater mollusks. A coal seam is exposed on the south side of Cape Bohemian, underlying sandstone and resting on shale or shaly sandstone. Leaves abound above the coal, *Ginkgo*, *Baiera*, with cycads and some ferns, and *Elatides* is under the coal. Bituminous sandstone with plant impressions and a seam of coal was seen at another locality, where, somewhat higher in the section, there is a soft clean sandstone with the same plants as well as freshwater mollusks, *Lioplax* and *Unio*; but still higher is a deposit with fossil wood and marine mollusks. The same group was seen on the shore of Van Keulen Bay, where the lower portion contains some thin coal seams and some clay ironstone.

Siberia.—Coal seams of Mesozoic age are present in extensive areas within Siberia. Their place in the column had not been determined when the description cited was prepared.²³ They were taken to be Jurassic, but they may be in part Rhaetic.

In the region between the Yenisei and Irkutsk rivers, the coal-bearing portion of the Jura, 60 to 90 meters thick, consists essentially of sandstone with subordinate beds of conglomerate and shaly clay. Fat and dry coals are here and boghead is not rare. A small area, about 10 kilometers square, of the freshwater Jura, near

²² A. G. Nathorst, "Beiträge zur Geologie der Bären-Insel, Spitzbergens, und des König-Karl-Landes," *Bull. Geol. Inst. Upsala*, Vol. X., 1910, pp. 362, 363, 365-369.

²³ "Aperçu des explorations géologiques et minières le long du Transsibérien," publié par le Comité Géologique de Russie, 1900, pp. 68, 86-92, 97, 179, 182, 190, 197, 199.

Tcheremkhovo in the government of Irkutsk, shows about 65 meters of friable sandstone, in which are 3 coal seams from a half meter to nearly 3 meters thick. The coal is good, caking and has from 3 to 10 per cent. of ash, though occasionally it has more, in one case, 25 per cent. The sulphur is low.

The Transsiberian railroad crosses the brown coal basin of the Middle Tchoulym River between the cities of Mariinsk and Artinsk. In this basin, embracing not less than 7,000 square kilometers, the rocks, almost horizontal, are sands, argillaceous sands, gravels, sandy or plastic clays, freshwater limestones and coal. The mass is 260 meters thick and contains numerous lenticular seams of brown coal. These have small areal extent, the largest being 2 or 3 kilometers long by a kilometer wide, but the maximum thickness in the lenses is from 2 to 6 meters, though in some instances it is far greater, 14 meters at one locality. The coal ordinarily rests on clay, with an intervening faux-mur, and passes upward into a friable coaly material, resembling peat, on which rests clay or sand. This brown coal is excellent, that from the mined portions of the lenses having barely 3 per cent. of ash, and the quantity in this field is said to be "colossal." Another area of brown coal was seen on the Upper Tchoulym River, but the quality is inferior, there being at times as much as 30 per cent. of ash. In other areas, farther west, some seams of brown coal are very thick. In the extensive region along the Angora River, the coals approach boghead in their general features and they have from 10 to 34 per cent. of ash; but some of the seams yield excellent caking coal.

No Mesozoic coal is reported from the Transbaikal region, where Jurassic deposits seem to be wanting; farther east, in the Upper Amur Basin, some coal seams were observed, which are thin and of no economic importance; but on the divide between the Amur and the Zéia Rivers, Jurassic beds occupy a vast area and consist of gray or greenish sandstones with conglomerates and coal seams. Excellent coal has been obtained from a seam on the Grande-Bira River. In the eastern provinces, rocks were found similar to those of central Siberia, with several seams of coal, one to 2 meters thick and yielding anthracitic as well as caking coals.

New Zealand.—According to Hutton,²⁴ conditions favoring accumulation of coal existed in New Zealand at several horizons, but only during brief periods. The seams are nowhere thick enough to repay mining. One, 6 feet, is merely carbonaceous shale with numerous streaks of coal.

Alaska.—The Jurassic area of northeastern Alaska was examined by Collier,²⁵ who made a reconnaissance survey of the Corwin formation, probably Upper Jurassic, between meridians 163 and 165, beyond the 69th parallel. The formation is present at 100 miles farther east and notes by other explorers lead to the belief that it extends far inland; Collier's studies were confined to the Arctic coast line. Lithologically, the formation consists of thinly bedded shales, conglomerates, sandstones and coal seams. Shales predominate, more or less calcareous, gray brown to black and vary from mere mudstone to sandy shale. The sandstones and conglomerates are few and seldom exceed 10 or 12 feet. The pebbles are of quartz and chert, the largest being about 4 inches in diameter. The thickness is at least 15,000 feet and the coal area within the district covers not less than 300 square miles. Mining operations were insignificant and the studies were made almost wholly upon outcrops.

The coal seams appear to be in two groups, Corwin, above, and Thetis, below, separated by a great thickness of barren measures.

The highest seam in the Corwin, 4 feet, 6 inches and without parting, is enclosed in black shale or shaly sandstone. Some thin beds and impure coals were seen in the interval, 1,000 feet, to the next workable seam, which is 5 feet thick and divided by two thin partings of clay. Its roof is shaly sandstone and the floor is hard clay. The next seam, 500 feet lower, is the Corwin, which was opened many years ago, but the opening was inaccessible at the time of Collier's visit, being covered by a great snowdrift. This seam, about 1,000 feet above the bold conglomerate of Corwin Bluff, is said to be 16 feet thick, of which 7 feet are practically clean coal,

²⁴ F. W. Hutton, "Geology of Otago," Dunedin, 1875, pp. 99, 100; Geol. Survey of New Zealand, Repts. for 1873-74, p. 36.

²⁵ A. J. Collier, "Geology and Resources of the Cape Lisburne Region, Alaska," U. S. Geol. Survey, Bull. 278, 1906, pp. 27, 28, 37-40.

the rest being so badly broken by partings as to be worthless. The interval to the conglomerate of Corwin Bluff is filled with shale, holding at least 8 coal seams. The cliff could not be reached and the thicknesses of only three could be estimated: 4, 12 and 30 feet. An irregular seam underlies the conglomerate and rests on sandstone; it is in pockets but the coal is good in spite of the distortion. Lower seams were seen in the next 1,000 feet, not distorted, as they are in soft shale, which took up the strains.

Below the lowest seam of the Corwin is a series of barren measures, about 8,000 feet, in which only thin streaks of coal were seen; this overlies the Thetis group, which is reached at 6 miles east from Corwin Bluff and its highest seam is known as the Thetis, 6 feet thick, and opened many years ago. Ten seams were found in the succeeding 700 feet of shale, only two of which are likely to prove important.

This necessarily imperfect record suffices to show that the quantity of Jurassic coal in northwestern Alaska is enormous. Some cannel is said to have been found in the Corwin group, but Collier saw none.

JURA-TRIASSIC.

Generally speaking, it may be said that where the succession is complete, there is always a portion of the column, which is debatable ground, and there is difficulty in determining the boundary between formations. In some cases, unconformities due to folding or to erosion offer evidence on which to base a final determination; but such areas, though large in square miles, often mark only local adjustments, similar to those observed within formations, but which no one regards as important. Occasionally, the matter is complicated by lack of fossil remains. Such is the condition in a great part of Australia, where it has not been possible to divide satisfactorily the great mass between the Permo-Carboniferous and the Cretaceous. Jack and Etheridge²⁶ recognize a Trias-Jura system in Queensland, which Jack has divided into the Ipswich and Burrum formations.

²⁶ R. L. Jack and R. Etheridge, Jr., "Geology, etc., of Queensland," 1892, pp. 300-39, 366.

The Ipswich or newer formation occupies an area of about 12,000 square miles in southeastern Queensland and consists, for the most part, of fine conglomerates, grits, sandstones and shales with seams of coal and beds of fireclay. At a few miles south from Brisbane, W. H. Rands saw a mass of coal and carbonaceous shale, 12 to 13 feet thick. The "best" coal is in the lower portion; some pieces of hard bright coal, free from shale partings, contained 24 per cent. of ash. A seam in the same neighborhood shows (1) coal, 4 inches; (2) shale, 2 feet, 2 inches; (3) coal with bands of shale, 1 foot, 6 inches; (4) good, hard coal, 5 feet, 3 inches; (5) shale, 3 inches; (6) fireclay, 2 inches; (7) shale with bands of coal, 5 feet, 6 inches; (8) fireclay, 1 foot, 4 inches; (9) coal, 2 feet; (10) black band, 8 inches; (11) coal, 5 feet, 3 inches; (12) hard sandstone, 2 inches; (13) coal, 4 inches; in all, 24 feet, 11 inches with somewhat more than 14 feet of coal aside from the thin bands of coal in the thick shale division. A piece from No. 11 had 19 per cent. of ash. A shaft in this district cut one foot of cannel and, lower down, a seam of hard and bright bituminous coal, but the sample from it contained 31.61 per cent. of ash. The coals in this district are much broken by partings and high in ash; yet, there were times and places during and in which conditions favoring accumulation of clean coal existed; for a piece taken from a thin bench at one locality showed only 2.5 per cent. of ash.

The type district, that of Ipswich, about 30 miles west from Brisbane, was examined by A. C. Gregory. The best seam near Ipswich is 5 feet, 6 inches thick and contains 3 to 4 feet of coal, of which the best contains about 11 per cent. of ash. Beyond Brisbane River, the seams contain comparatively little coal and that is usually poor; but one of them becomes 4 feet, 6 inches at one locality and its coal has barely 9 per cent. of ash. This seam, however, deteriorates in all directions. This variability characterizes seams throughout the district; a thin seam may be disseminated in a mass of coaly shale, 20 to 30 feet thick. Gregory ascertained that the quality of coal bears some relation to its distance from the northern margin of the field, the ash increasing in that direction—that is, toward the border of the great valley in which the coal measures accumulated.

Going westward from Ipswich along the railway to Toowoomba, one reaches lower members of the formation, which have seams of cannel at many localities; the associated rocks are sandstone and shale. A thick seam on Blackfellow's Creek shows (1) coal, 1 foot; (2) fireclay, 1 foot; (3) coal, 6 feet; (4) white clay, 1 foot; (5) coal, 1 foot; (6) clay shale, 1 foot; (7) coal, 1 foot; (8) a thick bed of fireclay and shale. The coal in all benches is hard cannel, so that the whole of it is available. There are some seams of bituminous coal, caking, in this region but they are thin. Near Clifton station on this railway, a shaft cut three seams at 60, 80 and 100 feet from the surface. The lowest is a rich, very hard "oil coal"; the middle seam yields good caking coal and the highest, 4 to 5 feet thick, consists of bright bituminous to dead-black "oil coal," all being hard and tough. From the description, it would appear that the cannel is in lenses within the bituminous coal. The town of Warwick is on an outcrop of sandstone, which holds a great quantity of fossil wood, usually replaced with iron ore. The coal between Warwick and Walloon is mostly cannel, which yields a high percentage of gas or of oil and paraffin.

The only mollusk recognized is *Unio. Vertebraria* is in the underclay of a coal seam near Tivoli. From various horizons, there were collected 11 genera of ferns, 4 of cycads and 5 of conifers.

The Burrum formation or lower portion of the Trias-Jura is exposed in a continuous area of about 3,000 square miles as well as in some small areas. Not much development had been attempted prior to 1892, owing to lack of railroad communication; but comparatively extensive operations were under way near Howard, about 150 miles north from Brisbane. There W. H. Rands measured a section of 1,015 feet, representing the top fifth of the formation and containing 6 seams, 1 foot, 8 inches to 5 feet thick, which were mined. These coals are of good quality, low in ash, are caking and yield a good gas for illuminating. The coal seams generally are irregular. The fauna is scanty, a few specimens of *Corbicula* and of *Rocellaria* have been seen. The flora is almost equally scanty and is represented by a few fragmentary specimens belonging to 4 genera of ferns, 2 of cycads and one conifer.

In New South Wales,²⁷ strata seen on the Clarence River District have some insignificant streaks of coal and the flora has Jurassic affinities. The rocks are conglomerates, sandstones and shales, and the coal seams are unimportant. The Wianamatta beds, about 700 feet thick, are older and more argillaceous. Entomostraca occur in the upper layers. The coal seams are, at most, only a few inches thick. The Hawkesbury series, resting on the Permian-Carboniferous, is about 1,000 feet thick and consists of yellowish-white sandstone with a few beds of shale and conglomerate and some streaks of coal, without economical importance. The sandstones show much false bedding, usually directed toward the northeast, but reversal of the currents is evidenced by occasional inclination in the opposite direction. Contemporaneous erosion of the sandstones is proved by old channel-ways filled with gravel and angular boulders are not rare. Wilkinson thought the false bedding due to currents in shallow water; but he cites J. E. Tennison-Woods, who asserts that the peculiar structure is evidence that these sandstones are a wind-blown formation. Plant leaves and fragmentary stems as well as remains of fishes are in both formations but no remains of marine animals had been discovered. The later studies of the New South Wales geologists make it clear that the relations of the Wianamatta and Hawkesbury to the Triassic are very close.

TRIASSIC.

The term Trias is of German origin; on much of the continent, the system is triple or was recognized as triple, being divided into the Keuper, Muschelkalk and Bunter. In later years, the Rhætic or Infra-lias has been taken to be more closely allied to the Trias, so that now the divisions are four.

Within Great Britain, Rhætic, Keuper and Bunter have been recognized, but the Muschelkalk or limestone division seems to be wanting. The several formations consist of conglomerates, shales, marls and sandstones; the Bunter in considerable areas passes downward gradually into the Permian. Rock salt and gypsum are in the

²⁷ C. S. Wilkinson, "Notes on the Geology of New South Wales," Dept. of Mines, Sydney, 1882, pp. 53-55.

Upper Keuper. The whole mass is apparently without coal. The sandstones in very many cases are false bedded, suggesting wind-drift structures; footprints abound at numerous localities. The general features have led some English geologists to believe that the Trias of that country was formed during desert conditions. On the continent, coal was formed during the Upper Keuper as well as in the Lower or Kohlenkeuper. There appears to be none in the Muschelkalk or Bunter sandstone. Salt and gypsum are in the marls of Upper Bunter, footprints are numerous in the Middle, while the sandstones of the Lower Bunter are usually false bedded and footprints are abundant. As in England, the Bunter of north and central Germany passes gradually downward into the Permian.

Sweden.—Coal is present in the Rhætic of Sweden. Hebert²⁸ states that at Ramloesa, 4 or 5 kilometers southeast from Helsingborg, he measured a section of somewhat more than 240 feet, consisting mostly of black shale, with a streak of coal, 2 centimeters, at the top, and another, 3 decimeters, at the base. The latter was mined. The shales associated with this coal yielded no plant remains to Hebert, but other collectors had obtained specimens, which are in the museum at Lund. Plant impressions were seen in a sandstone, midway in the section. Plant structure is distinct in the coal. Geikie,²⁹ summarizing results obtained in this region by Nathorst, E. Erdmann and G. Lindstrom, says that the area of these Rhætic beds is about 250 square miles. They have been divided into a lower, freshwater group, containing workable coal seams, and an upper, marine group with only poor coal but abundant marine organisms. Clay ironstone occurs in the lower group and beds of fireclay underlie the coal seams.

France.—Servier³⁰ described the Keuper area of the Vosges, northeastern France. The Upper Keuper is triple; variegated marls on top, dolomitic limestone in the middle; the lower division is (1) variegated marl, 1.50; (2) micaceous sandstone, more or less

²⁸ E. Hebert, "Notes sur les grès infraliasiques de Scanie (Suede)," *Bull. Soc. Geol. France*, II., Vol. 27, 1870, pp. 366-376.

²⁹ A. Geikie, "Text-Book of Geology," 3d ed., 1893, pp. 870, 871.

³⁰ M. Servier, "Notes géologiques sur les mines de houille de Norroy (Vosges)," *Bull. Soc. Ind. Min.*, t. IV., 1858-59, pp. 384-398.

argillaceous, with abundant impressions of plants and animals, 3.30; (3) laminated shale, argillaceous, with leaf impressions, 0.05 to 0.15; (4) coal, 0.25 to 1.00; (5) black-brown carbonaceous shale, with great abundance of vegetable impressions, ill-preserved but remarkably like modern swamp plants, such as reeds and ferns, 0.50; (6) marly shales with plant impressions and *Posidonia*, 0.90; (7) shaly sandstone with remains of plants, 0.50; (8) silicious fetid limestone, 3.00; total, 10.40 meters. This rests on the Lower Keuper, mostly variegated marls with gypsum and salt. The dolomite marks a notable change in conditions; below it, the deposits are micaceous and sandy, with abundant remains of plants and animals; but above it, marls predominate and remains of any sort are rare.

The coal seam varies greatly in thickness; at times it bifurcates, at others it disappears. These variations are not due to disturbance as the dip is less than 3 degrees. Kidneys of dark calcareous iron ore are in the coal, now concentrated under the roof but again scattered throughout the seam. Pyrite is abundant. Where thickest, the seam is triple, showing (1) upper bench, variable, consisting at times of alternating bright and dull laminations, when the coal is rejected as it burns badly and is not reduced to ash; commonly, however, it is brilliant black and an excellent fuel; (2) middle bench, not always present; its coal is glossy black, is almost uniform, burns well and is reduced to red ash; it encloses vegetable remains, some of them root-like; (3) lower bench, has brilliant black coal, yielding a brown powder.

The quality and thickness improve toward the north. At the south, near La Marche, Romain and Talliancourt, it is replaced with clays containing great numbers of tree stems. Mining begins farther north near la Rouville and Croinville, where the thickness is 0.15 to 0.30; at Norroy, it becomes 0.40 to 0.80, but at Gemmalaincourt and Parey it is 1 meter. Fragments of shale, quartz and sandstone with rounded angles occur occasionally in the coal. The lenticular form of the seam is distinct.

The same horizon has been recognized at widely separated localities in France, though coal is rarely present. Rouville,³¹ describing

³¹ P. de Rouville, *Comptes Rendus*, t. 48, 1857, pp. 696-698.

the Trias of Aveyron and Herault, states that the abundant coaly impressions of plants in Keuper beds had induced many to search for coal but without success. Grand'Eury saw some coal in the Keuper of Nice which contains stems of *Equisetites* and in the shale are rootlets of these plants. At Gemmalaincourt, he found *Equisetites* roots in the underclay but bark and seeds are in the coal.

Germany.—The Lower or Kohlenkeuper contains at many places in Germany the Lettenkohle, which Credner³² describes as a carbonaceous clay, filled with plant remains and at times passing into impure coal. Near Siwierz in Poland there are 3 beds 30, 50 and 80 inches thick. Sandberger³³ published records of numerous sections of Triassic deposits obtained in Unterfranken of Bavaria. He offers no comments, but the records suffice to prove irregularity of deposit. Two Lettenkohle sections near Würzburg exhibit the triple structure. That obtained between Würzburg and Rothen-dorf shows at top of the middle division a yellow fine-grained sandstone with many erect roots, while at base of the division is a zone with abundant remains of plants. This rests on the Hauptsandstein of the lower division, part of which is diagonally bedded. No coal is present. In the other section, between Würzburg and Schweinfurt, plant remains abound in both the upper and the middle division, but coal is wanting; the top layer of the Hauptsandstein is argillaceous sandstone with many roots, while at the base is a fine-grained sandstone with irregular layers of pulverulent coal. A section of the Krainberg gives these details respecting the middle division: (1) clay shale, with Lettenkohle at base, 3.66; (2) shale, 0.15; (3) sandstone with roots, 1.18; (4) clay shale, 1.18; (5) Lettenkohle and plants, 0.70; (6) ochreous limestone, 1.32; below which to the base are sandstone, ochreous limestone, clay shale and sandy shale, all apparently without coal. The sandstone, No. 3, is the root bed for plants which produced the impure coal above it.

The conditions seem to have been much the same at all localities where Lettenkohle exists. The coal is irregular in occurrence and

³² H. Credner, "Elemente der Geologie," 8te Aufl., 1897, p. 535.

³³ F. v. Sandberger, "Die Lagerung des Muschelkalk- und Lettenkohlen Gruppe in Unterfranken," *Verh. Phys. Med. Gesells. Würzburg*, Band XXVI., 1893, pp. 200, 205, 206.

usually is of little value. The influx of foreign matter into the petty swamps was too great to permit accumulation of clean coal; but root-bearing underclays and soils of vegetation without coal are characteristic features. v. Gümbel³⁴ states that Lettenkohle from Guildorf in Württemberg and Schweinfurt in Franken gives a weak brown tint to solution of caustic potash; it is easily decomposed by Schultze's solution and woody structure is distinct in the residue. Rhætic coal from near Bayreuth reacts to Schultze's solution as does Lettenkohle. Many layers of this coal appear to consist almost wholly of pollen exines.

Austria.—An important area of Triassic coals is in Upper and Lower Austria; these belong to the Lunzer beds of the Upper Keuper. A less important area is in Südtirol, where coal is in the Wengener beds at the base of the Keuper.

The Upper Keuper area was studied by Lipold³⁵ and his associates. The Triassic deposits are in the interior of the northeastern Alps and they have suffered more from disturbance than have the Liassic beds of that region. Lipold reports that near Baden, on the eastern side of the area, the coal and shale are so crushed and intermingled that definite sections cannot be made and that all attempts to obtain merchantable coal have failed. No mollusks were seen but *Calamites arenaceus* and *Pterophyllum longifolium* are not rare.

Hertle found only unimportant seams in the Lunzer sandstones near Ramsau; but in Kleinzell, where the sandstone is much distorted, 3 thin seams were seen, all marked by extreme variations in thickness, which seem to be due to compression during folding. At Lilienfeld on the Traissen River, the dip is from 40 to 70 degrees and the coal seams, being between sandstones, have been distorted seriously. The thickness of one seam varies from one inch to 9 feet within a short distance. The Lunzer sandstone is distinctly of freshwater origin in this district, but it is between the Opponitzer above and the Goslinger below, both of them calcareous and containing marine fossils. The workable coal seams, 4 and 2 feet thick,

³⁴ C. W. v. Gümbel, "Beiträge, etc.," p. 160.

³⁵ M. V. Lipold, G. v. Sternbach, J. Rachoy, and L. Hertle, "Das Kohlengebiet in den Nordöstlichen Alpen," *Jahr. k. k. Geol. Reichs.*, Band 15, 1865, pp. 62-159.

are in a mass of black shale, about 70 feet thick. *Equisetum columnare* is abundant in the black shales and beautiful specimens have been obtained from the roof of the upper seam. This seam, 4 feet thick where first seen, is from 3 to 24 feet. Occasionally it divides into two or more benches, of which only one is persistent. The coal of Lilienfeld and Kleinzell yields 72 to 74 per cent. of good coke and ash is from 8 to 14 per cent. in the raw coal.

Hertle examined the area near Kirchberg on the Pielach River where the black shale mass has 4 seams of coal. This shale is 40 feet in one tunnel, 48 to 60 in another, while in a third it is not less than 100 feet. In one tunnel, the middle seam is 72 feet above the lower one; followed westward, the interval becomes 50, 30 and 18 feet. A similar convergence is that of the middle and upper seams, which actually unite with increased thickness. These relations existed before disturbance occurred. Dips in this district are from 40 to 70 degrees. The coal throughout is tender and caking, giving 67 per cent. of good coke; but the ash is high, averaging 15.8 per cent. In the Rehgarten area, the coal is cleaner, having only 9 per cent. of ash. Here distortions of the rocks are few but other troubles are encountered; the seams thin away and frequently they pass into carbonaceous shale. Hertle's descriptions make it clear that the seams are lenses, sometimes joined by carbonaceous shale, but at other times wholly separate. The "horseback" seems to be a feature here, as in the older as well as in the newer coals. One tunnel reached sandstone, with no admixture of clay or coal, at 480 feet from the mouth. It was pushed through the rock and again reached the coal. The lower seam at Loichgraben yields a good coal, but that from the upper seam has 52 per cent. of ash, though it looks like excellent coal.

Rachoy found plant-bearing shales as roof of coal seams near Lunz and he says that, near St. Anton, a bituminous limestone is the roof in some mines. The coal at several localities is good but at others the ash is very high, while the coal externally resembles the best in the district. This area is on the westerly side of the Lunzer region and, in most cases, the seams are thin.

Zincken³⁶ states that plant-bearing shales are the roof at many

³⁶ C. F. Zincken, "Ergänzungen, etc.," 1878, pp. 110, 111.

localities; that the coal seams are distinctly lenticular in some of the important districts, and that the coal is caking at some places, but non-caking at others.

The Wengener beds are at base of the Keuper and rest on the Muschelkalk. Keyserling⁴⁷ found coal within these beds, west from Cordeville Valley on the southeasterly slope of Mt. Cordai in south Tyrol. The rocks are alternating tuff sandstones, red, green and brown clays and marls, interrupted by beds of limestone. All yield so readily to the weather that a detailed section cannot be made. The Hauptflötz, locally regarded as "workable," is from 4 to 5 decimeters thick and is well exposed in the bed of a stream, where it rests on dark limestone; elsewhere, it is frequently enclosed in clay and sandstone. The coal is laminated, some of it resembling brown coal but other portions are much like stone coal. The transformation is so far advanced that no trace of organic structure can be recognized by the naked eye, but the mode of occurrence convinced the author that it was derived from water-loving plants. The quantity of pyrite is remarkable. Coal rarely occurs at this horizon.

The Lunzer horizon was recognized by Lipold³⁸ in Carniola (Krain) who saw near Idria coaly shale with streaks of coal, but he could discover no definite seams.

Hungary.—Hantken³⁹ reports that in the Fünfkirchen region of Hungary a sandstone formation, 620 to 950 meters thick, underlies the Liassic coal complex conformably. Its coals appear to be local and in most cases they are too thin to be mined. Fossils are not abundant; at one locality, *Zamites*, *Palissya* and *Thaumatopteris* have been collected; another yielded *Cardinia* and *Acrodus*. This assemblage is accepted as evidence that the mass is of Rhætic age.

United States.—Triassic deposits of the Atlantic border extend in detached areas from Massachusetts to North Carolina. No coal of economic importance has been discovered north from Virginia, though thin streaks have been observed in Massachusetts, Rhode

³⁷ H. G. Keyserling, "Ueber ein Kohlenvorkommen in den Wengener Schichten der Südtiroler Trias," *Verh. k. k. Geol. Reichs.*, Jahrg. 1902, pp. 57-61.

³⁸ M. V. Lipold, *Jahrb. k. k. Geol. Reichs.*, Band 24, 1874, p. 445.

³⁹ M. Hantken, "Die Kohlenflötzen, etc.," pp. 104, 105.

Island and Pennsylvania. McCreath⁴⁰ states that P. Frazer had found coal in Triassic beds of York County, Pennsylvania, but neither he nor Frazer in his York County report gives a description of the deposit. According to McCreath, the coal is deep black, with pitchy luster, brittle and with conchoidal fracture. The proximate composition is: Water at 225° F., 4.310; volatile, 18.482; fixed carbon, 74.358; sulphur, 0.528; ash, 2.322. There is no tendency to cake and the gases burn with non-luminous flames. The dried coal absorbs water with great avidity, so that within a few hours it re-absorbs about 63 per cent. of the water originally present.

The important region known as the Richmond coal field is reached at a little way north from the James River in Virginia. Mining operations were begun a century ago and for many years they were on extensive scale. Irregularities in the seams and the many faults made mining costly and the local coal was displaced by anthracite from Pennsylvania. Operations now are unimportant.

Fontaine,⁴¹ in the introduction to his descriptions of fossil plants obtained in the Richmond and adjacent areas, gave a synopsis of the relations. The Triassic rocks occupy several areas in a belt extending from Rhode Island to South Carolina. The most westerly area, termed the Palisade, is almost continuous from the Hudson River across New Jersey, Pennsylvania and Maryland to about 75 miles southwest from the Potomac River in Virginia; it is without coal. The small area of Buckingham County, Virginia, is east from the last and like it is without coal. The Dan River area, still farther east, is in Virginia and North Carolina; it has some coal in the latter state. The Cumberland (Farmville) area is small but has some coal seams of local importance. The Richmond, 30 miles east from the Cumberland, is the last in Virginia, but the Deep River, still farther east, is in North Carolina and extends to the South Carolina border.

Red beds prevail in the western areas but they are insignificant in the Cumberland and Richmond areas. Fontaine recognized three

⁴⁰ A. S. McCreath, Second Geol. Survey Penn., Report MM, 1879, p. 103.

⁴¹ W. M. Fontaine, "The Older Mesozoic Flora of Virginia," U. S. Geol. Survey, Mon. VI., 1883, pp. 1-7, 12-16, 32, 45, 79.

distinct groups in the Virginia areas: the upper group, consisting of loose granitic sandstone or sandy shale, containing no coal but much lignite, resembling jet; silicified wood is not rare; a middle group, coal-bearing, with a large proportion of black shale; a lower group, sandstone and shale. The sandstones of the lower group are not easily distinguished from the underlying granitoid gneiss and are 100 to 600 feet thick in the Richmond area. The middle group is 100 to 200 feet thick in the same field, where it usually has two thick seams of coal—but the number, thickness and quality vary greatly. At many places the roof is a plant-bearing shale; *Equisetum rogersi* is usually associated with *Macrotaniopteris* and its casts are present in the coal. *Schizoneura* occurs in the underclay of the main seam. The plants described by Fontaine are conifers, cycads, equiseta and ferns.

Shaler and Woodworth⁴² applied names to Fontaine's groups; the Chesterfield or upper group is 2,500 feet thick and consists of sandstone above, shales below; the Tuckahoe, equivalent to the middle and lower groups, consists of the coal measures, 500 feet, more or less, sandstones and shales, 0 to 300 feet, and boulders, 0 to 50 feet.

The Richmond field was discussed many years ago by geologists, who studied it when the mines were still in operation.⁴³ It is well to summarize the statements of each observer as the conclusions reached by them have been regarded as not in agreement and they appear to be in some respects contrary to those reached by observers who have studied the region since mining operations practically ceased.

Taylor reported that the deposits occupy a narrow trough, which deepens so rapidly toward the median line that coal mines are pos-

⁴² N. S. Shaler and J. B. Woodworth, U. S. Geol. Survey, 19th Ann. Rep., Part II., 1899, p. 423.

⁴³ R. C. Taylor, "Memoir of a Section Passing through the Bituminous Coal-Field near Richmond, Virginia," *Trans. Geol. Soc. Penn.*, Part I., 1835, pp. 275-297; W. B. Rogers, "Reprint of Annual Reports on Geology of Virginia," 1884, pp. 62-69; "On the Age of the Coal Rocks of Eastern Virginia," *Reps. Amer. Asso. Geol. and Nat.*, 1843, pp. 298-316; C. Lyell, "A Second Visit to the United States of North America," 2d ed., London, 1850, pp. 281-287.

sible only on the eastern and western margins. The maximum thickness of coal, as far as can be ascertained, is near the middle of the eastern border, whence it thins toward the north and the south. The coal in all mines, of which Taylor gives measurements, is near the base of the section and rests on the granite or is separated from it by, at most, a few feet of shale. The overlying rocks, for about 400 feet, as cut in shafts on both sides of the trough, are mostly grits, sometimes conglomeratic, with interstratified gritty micaceous, carbonaceous or argillaceous shale.

In the northeastern part of the trough, he saw two seams, 5 and 3 to 4 feet, separated by 10 or 12 feet of slate and about 10 feet from the granite, there being a thin seam in the latter interval. On the northwestern side, the seams are 30 feet apart and are 6 to 16 and 4 to 8 feet thick. These are said to unite farther north. The lower seam, of rather inferior quality, rests on the granite. On the eastern border, the Chesterfield shaft shows (1) coal shale, 6 feet, 10 inches; (2) coal, 5 feet, 6 inches; (3) coal shale, 3 feet; (4) coal, 1 foot, 6 inches; (5) hard grits, 2 feet, 6 inches; (6) shale and thin coal, 2 feet, 6 inches; (7) coal, 7 to 40 feet; (8) granite. The lowest coal has some variable partings. The sections on this side of the trough are much alike; but the coals, 4 and 6, are not always present and not infrequently some shale was seen between the coal and the granite.

As the mines had been worked extensively prior to Taylor's visit, he had opportunity to examine considerable spaces from which the coal had been removed so that the underlying granite surface was exposed. Not rarely a boss of granite rose through the lower division of the seam; in such cases, the work was usually abandoned; but occasionally a drift was carried around the boss and entered a body of coal, filling a hollow, 50 or 40 feet deep. There is no parallelism between top and bottom of the seam. The roof is irregular, rising and falling, and the depressions sometimes reach the floor, but they never conform to the irregularities of the granite surface. In spite of these irregularities, the lamination of the coal is wholly undisturbed. The lower part of the seam is less clean than the upper, but the coal is fat and coking throughout.

Rogers was studying the region at the time of Taylor's visit.

His report, published in 1836, contained a brief statement which adds important observations while confirming those made by Taylor. He discovered that the overlying sandstone group apparently overlaps the coal measures and that the lowest coal seam is separated from the granite in most cases by only a few feet of shale. The coal thickens toward the center of the basin and, as a rule, the higher seams are the best.

In the Midlothian and several adjacent mines, there is ample evidence to prove that the coal accumulated in saucer-shaped basins to the thickness of 40 or 50 feet, while on the eminences of the same floor it is thin. On the south side of the James River, the River pit was abandoned when the granite floor rose almost to the sandstone roof. Near Tuckahoe, on the north side of the river, the coal was found central in a small, isolated, cup-like depression. This coal rose gently in all directions from the shaft and thinned from 5 to 2 feet toward the edges of the shallow basin. This is several hundred feet in diameter and its strata vary little from the original nearly horizontal position. "Everything lends countenance to the opinion that the surface of the primary rock, previous to the deposition of carbonaceous matter, was a valley of rolling outlines, occupied by hollows and elevations, causing the first layers of matter, which were thrown down, to be deposited in greater thickness in some places than in others. As the lowest coal seam is separated from the crystalline rock by only a very few feet of shale and in some cases by none at all, it appears likely that the distribution of the coal was made unequal in thickness from the very commencement."

In his later memoir, discussing the relation of the plant remains, Rogers stated that the most abundant plants are *Equisetum columnare*, *Taniopteris*, and a large species of *Zamites*. These occur in vast numbers immediately upon the coal or interlaminated with it. They are accompanied by *Calamites*, *Pecopteris* and *Lycopodites*. The *Equisetum* is so abundant, at times, as to give a coarse coal consisting of alternate laminations of coal and shale with occasionally 30 laminations to the inch. Ferns are rare, aside from the great *Taniopteris*. The only animal remains are those of fish and some teeth supposed to be reptilian. The fish remains are in dark

shale associated with the coal; but scales along with teeth and plant impressions were seen at times in the upper part of the coal itself. Rogers saw nothing answering to the *Stigmaria*-clay of the Carboniferous. These descriptions by Rogers make clear that a faux-toit is the ordinary feature; while the presence of animal remains in the coal indicates existence of pools on the swamp surface. Underclays are in this field, but they do not hold *Stigmaria*, for *Lepidodendron* and *Sigillaria* had become extinct.

Lyell visited this field in 1845. He was much impressed by the fact, already noted by Rogers, that stems are found so often erect and compressed vertically; he could think of no reason to doubt that the greater number of such plants, in beds above and between coal seams, and which he saw at localities miles apart, had grown where they are now enclosed in sand or mud. The great coal seam rests at times directly on the granite, but at others is separated from it by an inch or two of shale. He was inclined to think that the absence of deposits between the coal and the granite may be due to disturbances, which were considerable, as shown by the extensive faults.

Mining operations ceased at nearly all localities about 50 years ago and the old mines, abandoned, soon became inaccessible. A long interval passed before new studies were made and few⁴⁴ of these dealt with details respecting the coals. Fontaine's detailed stratigraphical work was done near Clover Hill in the southeastern part of the field, where some work was going on at the time of his examination. There he found thick deposits between the coal and granite and assigned to them a thickness of 100 to 600 feet. Clifford stated that in outlying districts of the Richmond basin there is only one coal seam, usually of great thickness and separated from the granite by a thin bed of shale, often not more than a few inches. This refers to the northern part of the field. It should be noted here that the earlier observers regarded the benches of coal as separate seams.

⁴⁴ W. M. Fontaine, "The Older Mesozoic Flora of Virginia," U. S. Geol. Survey, Mon. VI., 1883; W. Clifford, "Richmond Coal Field, Virginia," *Trans. Manch. Geol. Soc.*, Vol. XIX., 1888, p. 320; I. C. Russell, "The Newark System," U. S. G. S. Bull. 85, 1892, pp. 38-40, 63; N. S. Shaler and J. B. Woodworth, "Geology of the Richmond Basin, Virginia," 19th Ann. Rep. U. S. G. S., Part II., 1899, pp. 423-426, 429, 483.

Russell asserts that the coal seams of the Richmond basin are irregular and greatly disturbed by faulting. They are not continuous though they are approximately at the same horizon. He regards them as overlapping lenses, individual deposits thinning away. A thin seam in one mine may be the important one in another. As to the interval to the granite, he cites O. J. Heinrich, who in 1879 reported that at Midlothian the coal is at 570 feet from the granite; also Fontaine, who in 1883 stated that the interval at Clover Hill is 250 feet. Russell suggests that the luxuriant subtropical vegetation of these Triassic lowlands has its nearest modern analogue in the fern forests of New Zealand. The ground must have been covered with ferns, above which rose equiseta and the great ferns with palm-like leaves; cycad forests with pines of Araucarian type covered the upland.

Shaler and Woodworth report that the lower barren beds, underlying the coal measures, are not always recognizable with certainty; sometimes the barrenness may be due to lack of coal accumulation at the locality, but there are places where the coal group is fully developed and where a considerable thickness of barren rocks was seen. These authors offer no explanation of the origin of the boulder beds occasionally observed at the base of the section. They consist of granitic boulders with a partial bedding of reddish gritty sandstone. Plate XXI. of the report illustrates well the disintegration of the granite, which preceded deposition of Trias in this basin. This is remarkably similar to conditions observed by the writer in central France between Aurillac and Decazeville, where such disintegration is shown at many places. In the Decazeville basin, this preceded the deposition of the Coal Measures and the accumulations were mistaken for deltas by several observers.

Some have supposed that the great variations in thickness of the Richmond seams were caused by pressure during disturbance; but there appears to be no reason for resort to this explanation. Such swelling and contraction of seams is certainly common enough in disturbed regions, but there the structure of the coal is changed; it is exceedingly tender or it is rolled into flakes like pastry. But in the Richmond basin the lamination, according to Taylor and according to observations by the writer, is undisturbed in locali-

ties where the coal is very thick. Several observers have urged that the varying interval between the coal and the granite floor is likewise a result of disturbance. This suggestion may, perhaps, prove good for some localities but to the writer it seems unnecessary to resort to that hypothesis; Rogers's suggestion is far better, that the deposits were made on an irregular surface. This accords with the conditions observed in North Carolina as well as in Virginia.

Two Triassic areas are in North Carolina; the Dan River, at the northwest, is without coal in Virginia but has some irregular deposits in North Carolina; the Deep River, at the southeast, begins near the Virginia line and extends as a narrow strip southwestwardly into South Carolina.⁴⁵

Emmons's section in the Deep River area shows a triple structure: Upper red sandstones and marls; Coal measures, slates, shales and drab sandstones; Lower red sandstone with conglomerate at base. The red rocks, wanting in the Cumberland and Richmond areas of Virginia, reappear here on the southeasterly border. The middle group, about 1,200 feet thick, has fine-grained sandstones which frequently are rippled; the coal seams are few and very irregular but some of them have been opened. Russell states that at Egypt a shaft reached, at 422 feet from the surface, a coal seam showing (1) black shale; (2) coal, 2 feet; (3) black band, 1 foot, 4 inches; (4) coal, 1 foot, 1 inch; (5) slate, 6 inches; (6) coal, 7 inches. Another seam, 25 feet lower, has black band roof and floor and is one foot thick; the upper seam has black shale roof and floor. Both are irregular in thickness and Russell asserts that there is no reason to suppose that they are continuous in any considerable area.

The coals are indefinite within the Dan River area. Emmons reports that, near Leakesville in northern part of the area, a coal seam shows: (1) coal, semibituminous, 2 to 3 feet; (2) micaceous shale, 2 feet; (3) coal, shaly, 1 foot, 6 inches. This is very near the base of the coal group. The lowest rock at the southern extrem-

⁴⁵ E. Emmons, "Geological Report of the Midland Counties of North Carolina," 1856, pp. 228, 230, 235, 256, 257; I. C. Russell, *Bull.* 85, p. 41; W. C. Kerr, "Report of the Geological Survey of North Carolina," Vol. I., 1875, p. 143; R. W. Stone, "Coal on Dan River, North Carolina," *Bull.* 471-B, 1812, pp. 5, 6, 16.

ity, near Germanton, is a conglomerate of angular fragments of granite and gneiss, containing roots of silicified tree-stems penetrating and branching in the deposit. The stems are very abundant just above the conglomerate, so abundant as to suggest that they are remains of an ancient forest. Most of them are prostrate and occasionally one finds the roots converted into lignite. The great abundance of stems near Germanton in Stokes county impressed Kerr, who says "the public road being in a measure obstructed by the multitude of fragments and entire trunks and projecting stumps of a petrified Triassic forest; and similar petrifications are abundant in the Deep River belt, occurring in this as in the other among the sandstones near horizons of the coal."

Stone's examinations led him to assign a thickness of about 7,800 feet to the deposits within the Dan River area, where the mass rests on Archean gneiss. The zone of carbonaceous shale with coal is 250 feet thick and just below it, at about 1,000 feet from the base, is conglomerate with subangular fragments, which is absent from the northern portion of the area. The roots and bark of the silicified stems within this mass in some cases have been converted into lignite. Shafts have been sunk in many places but usually only black shale has been found. At one place, 37 inches of such shale with much coal was found. The Leakesville deposit is insignificant and its area is but a few square rods.

Triassic rocks are exposed in very many localities west from the 105th meridian to the coast but they appear to be without coal in both the United States and in the Dominion of Canada.

Mexico.—But coal is present in Triassic deposits of the Santa Clara field on the eastern border of Sonora, Mexico. Dumble⁴⁶ has given brief notes respecting the locality. The Rhætic age of the deposits was recognized by Newberry and Fontaine after study of the plant remains. The region has been disturbed greatly by igneous rocks, which have metamorphosed the coals. The heavier sandstones are uniform and are moderately coarse conglomerate grits, which have a few fragments of silicified wood and occasional imprints of stems. The shales and finer sandstones are excessively

⁴⁶ E. T. Dumble, "Triassic Coal and Coke of Sonora, Mexico," *Bull. Geol. Soc. Amer.*, Vol. X., 1900, pp. 10-14.

variable, sandy shales change abruptly into coarse massive sandstone or into clay shale. The shales generally are rich in well-preserved remains of plants, which, according to Fontaine, are allied to those of Virginia and North Carolina. The more massive slates hold silicified stems and branches of shrubs, while the finer-grained sandstones have tree-trunks up to one foot diameter. No false bedding was observed in the sandstones.

Coal seams are numerous, each prominent slate bed having one or more; but in all cases these are irregular. Near San Marcial, southeast from the area of detailed examination, much work had been done on supposed anthracite, which proved to be only black slate; but at localities north and northwest from the mining center two seams are known, 8 and 10 feet thick. Much of the thicker beds is composed of coal with concentric structure, "shelling out into eggs of greater or less hardness."

The coal has been affected by the igneous rocks and usually it is a hard anthracite, though occasionally it is coke. In two important openings on the coke, igneous rock is the roof; in another, it is the floor; but other pits show no igneous rock anywhere near the coke. In one seam of anthracite, there are pockets of coke near the middle, while in a seam of coke pockets of anthracite were found at the bottom. In several beds divided by partings, coke prevails in some benches, anthracite in others. The proximate composition of the anthracite is: Water, 4 to 8; volatile, less than 5; fixed carbon, 76 to 85; ash, 4 to 8 per cent.

SOME CHEMICAL FEATURES OF THE COALS.

Coals of various grades are present in the Jura and Trias. Lignite and bituminous coal are present in the Lower Oölite of Great Britain within practically undisturbed rocks and at nearly the same horizon; while high-grade bituminous coal prevails in the Lias of Austria and Hungary, where the rocks have suffered severe disturbance. The Lower Lias of Siberia yields high-grade bituminous in the Tcheremkhovo and Grande-Bira fields but typical brown coal in the great Tchoulym region, where the strata are little disturbed and the rocks are only slightly consolidated. The Jura-

Triassic coals of Queensland are high-grade bituminous as are those from the Upper Trias of Austria and Virginia.

Cannel has been reported from the Jura of Alaska, but Collier saw none. Cannel, however, is certainly present in the Steierdorf-Anina field of the Hungarian Lias. Hantken has given the proximate analysis of two samples from the Hauptflötz, which show

Moisture	1.10	Volatile	53.77
	2.60		55.91
Ash	14.67	Fixed carbon	46.23
	22.00		44.09

The cannel is evidently in lenses, as at other localities this seam has only bituminous coal. In the same field, the Middle(?) Lias has a great mass of black shale, portions of which yield from 3 to 7 per cent. of crude oil, from which paraffin and illuminating oil are obtained. In Siberia the Lower Lias coal of the Angora River field is mostly of boghead type, while in the Ipswich or upper Jura-Trias of Queensland cannel or "oil coal" is present in a large area. Jack has given three analyses of the material:

	Ash.	Volatile.	Fixed Carbon.
Blackfellows Creek.....	17	56	43
Clifton, top seam.....	10	53	46
Clifton, lower seam.....	16	55	44

The seams at Clifton are separated by a considerable interval, which holds a seam of caking bituminous coal. Cannel prevails in the Walloon district where some of it is rich, that at Jimbour yielding about 37 gallons per ton.

The coals vary greatly in tendency to cake. Collier reports that none of the Alaska coals tested for him gives a coke. His samples, however, were collected mostly from outcrops, where leaching had been energetic during a long period. "Crop coal," even in the Connellsville region of southwest Pennsylvania, yields only a wretched coke. In Austria and Hungary many seams have caking coal but that from others is non-caking. In Siberia, the coals of the Tcheremkhovo and Grande-Bira fields are caking but that of the great Tchoulym field gives only pulverulent coke. The Jura-Trias coals of Queensland are caking in some instances, non-caking in

others. The Upper Trias coals of Austria are usually caking and those of the Richmond area are always so. Apparently no relation exists between proximate composition and tendency to cake.

No reference to the presence of resins in coals of the Jura or Trias is made in any of the works to which the writer has had access. One observation by Witham, cited by Miller, bears upon the subject. In studying silicified stems of *Pinus eiggensis* from the Lower Oölite of Scotland, he discovered that the wood abounds in turpentine vessels or lacunæ, well defined and varying in size.

Mineral charcoal (Fusain, Faserkohle) is a characteristic feature throughout. At times, it forms thin partings in seams, but at others it is an important constituent of thicker partings, where its abundance suggests that the partings are merely residues from a considerable mass of peat. Occasionally it is in lumps, embedded in the coal or in a clay parting.

Sphærosiderite or clay ironstone is reported by all except a very few observers. It is present in the coal, in the underclays, and is scattered in the other rocks, while occasionally it is in layers of varying thickness. At times, it replaces the stems of trees or fragments of wood. Black band layers, associated with seams of coal, have been reported from the Ipswich formation of Queensland and from the Rhætic of North Carolina.

The Jurassic coals of Great Britain are lignite or very low grade bituminous. No analysis of the coals in France is available. The analyses of the Austrian coals, as officially given, are incomplete and afford no information for comparisons; but the coals are clearly high grade bituminous, for that of many seams is caking. Hantken has published many analyses of the Jurassic coals in the Steierdorf-Anina and Fünfkirchen areas, and Nendtwich made a number at a much earlier date. The Steierdorf-Anina samples have as proximate composition:

The low percentage of ash makes evident that the analyses are of specimens supposed to represent the average best coal from the mines. This, however, is unimportant here. The upper Liegendflötz is separated from the higher bed by about 300 feet of rock. No marked tendency to decrease of volatile downward is recognizable

	Water.	Ash.	Volatile.	Fixed Carbon.
Hangendflötz	1.94	1.72	33.77	66.23
	2.50	1.75	36.59	63.41
	1.55	3.10	32.47	67.53
Hauptflötz	1.74	1.28	35.04	64.96
	1.88	2.07	30.41	69.59
	2.10	7.26	39.94	61.06
	1.90	1.95	34.98	66.02
	1.70	2.21	30.22	67.78
I. Liegendflötz	2.25	2.56	32.23	67.77
	2.25	16.78	23.28	76.72
	2.25	2.56	29.22	70.78
	1.85	12.88	42.73	57.27
II. Liegendflötz	2.05	4.19	34.64	65.36
	1.85	3.44	30.77	69.23
	1.75	5.65	41.86	58.13

in this series. The samples from the lower seams, containing the high volatile, must be considered as consisting in part of cannel.

The analyses of the coals from the Fünfkirchen area, published by Hantken, are ultimate; reduced to pure coal, as were those from the Steierdorf area, they are:

Seam.	Water.	Ash.	Carbon.	Hydrogen.	Oxygen.
II.	1.50	24.93	89.6	4.5	5.8
IV.	1.10	13.03	81.6	4.3	14.0
VI.	1.10	5.10	88.1	4.6	7.2
XI.	1.58	7.80	91.7	4.3	3.9
XIV.	1.80	15.77	93.7	4.5	1.7
"	3.20	11.64	77.7	4.7	18.1
XVI.	1.00	13.67	93.4	4.6	1.9
"	5.44	7.28	85.7	4.3	9.8
XXIII.	1.60	15.45	82.9	4.2	12.8
XXIV.	2.70	9.85	86.0	4.7	9.2

The order is ascending. The sulphur is from 1.07 to 6.88 per cent.; but in the great mass of seams XI. and XII. it does not exceed 2.50. In IV. at Vasas there is but 1.23 but at the Colonie mine it is 6.88. The thickness of the seam and the proportion of sulphur are not in relation; some thin beds have little, others much. The coal of XII. yields a great quantity of illuminating gas, that from three other seams about two thirds as much, while that from others is much less. The two analyses for XIV. and for XVI. are from different localities, but only a short distance apart. The local conditions

differ little but the oxygen-content at Szabolcs is very much greater than at Colonie. The proportion of oxygen has apparently no relation to the depth below the surface.

The analyses by Nendtwich⁴⁷ show as a rule less ash in the Steierdorf coals than in those of Fünfkirchen but the oxygen is somewhat less.

The Lower Jurassic coals of Siberia, according to analyses given by the Comité géologique, show extreme contrasts. I. and II. are from the Tchoulym field and III. is from the Grande-Bira area.

	Water.	Ash.	Carbon.	Hydrogen.	Oxygen.
I.....	11.68	1.56	69.92	6.13	23.95
II.....	16.66	2.28	69.73	7.12	23.15
III.....	2.35	12.00	81.6	5.5	12.7

The brown coal obtained in other districts is much inferior, as ash is very high.

The Jura-Trias coals of Queensland are bituminous throughout. Jack reports only proximate analyses but these suffice to show the great difference in conditions:

IPSWICH GROUP.

	Water.	Ash.	Volatile.	Fixed Carbon.
I.....	1.00	24.35	32.42	67.57
II.....		19.00	27.7	72.2
III.....	1.32	31.61	29.3	70.6
IV.....	2.02	22.8	30.8	69.1
V.....	1.32	19.70	29.3	70.6
VI.....	8.10	2.50	43.29	56.70
VII.....		16.00	42.81	57.1

BURRUM GROUP.

	Water.	Ash.	Volatile.	Fixed Carbon.
I.....	2.50	2.50	32.00	68.00
II.....	2.00	8.00	31.25	68.75
III.....	2.25	2.10	30.47	69.53
IV.....	2.75	3.25	29.50	70.50

The Ipswich coals throughout are very high in ash, the specimen VI. being picked from a thin band; all the coals except VI. and

⁴⁷ C. M. Nendtwich, "Ungarns Steinkohlen, etc.," *Haidinger's Berichten*, Band IV., 1848, pp. 18, 21, 30.

VII. are coking; the high volatile in these last, so greatly beyond that of other coals within the same little area, suggests that perhaps they contain some cannel. The Burrum specimens are all from a very small area, where mining has been carried on extensively and they are from only two seams. II. and III. are from the bottom and top of the Lapham or most important seam. The ash is low throughout, showing that, in this area at least, the conditions were favorable to the accumulation of clean coal. All of the seams yield good caking coal, though they differ in the hardness; that from several seams is hard shipping coal whereas that from others, especially that from one, is tender and therefore inferior as a steam coal. There is nothing in the structure to explain this difference as the seams are separated by a small interval. The Lapham coal yields 10,200 cubic feet of gas per ton, with 14.73 candle power; this is the result of a trial lasting for 20 months.

The Triassic coal of Norroy, France, was analyzed by Regnault, who obtained 19.20 per cent. of ash. The ultimate composition of the pure coal is: Carbon, 77.23, hydrogen, 5.39, oxygen and nitrogen, 17.37. Servier asserts that the specimen was not fairly representative and gives the results of a proximate analysis by himself: Moisture, 10.00, ash, 9.20, volatile, 42.4, fixed carbon, 57.5. This he regards as a fair average composition. He thinks it is a transition from brown to stone coal but the distillate is alkaline, not acid.

The Upper Triassic coals of the Richmond basin are all of high-grade bituminous quality, are caking and for many years they were used in the manufacture of illuminating gas in New York, Philadelphia and other large cities. The available analyses are those reported by W. B. Rogers,⁴⁸ which represent the average of the coal as observed at the more important localities. Twenty-two analyses were made. The ash is below 6 per cent. in all except 7 and exceeds 11 per cent. in only 3. The volatile in pure coal varies from 30 to 40 per cent., south from James River, and from 25 to 35 in mines north from that river. Much of the basin is broken by dikes which in some portions have converted the coal into coke; but there are anomalies not due to the influence of igneous rock. Analyses of samples from the bottom, middle and top of the thick

⁴⁸ W. B. Rogers, "Report of Progress for 1840," reprints, pp. 532-535.

mass in one shaft show 40, 30 and 31.7 per cent. of volatile in the pure coal, with 10.82, 5.10 and 9.52 of ash. In a shaft, north from James River, the 4 divisions of the coal show a difference of about 4 per cent. in volatile, while the ash is 5.20, 22.20, 9.80 and 22.60 in the several divisions.

Stone, in his report already cited, has given analyses of the coal at Leakesville in the Dan River area of North Carolina. The seam is an insignificant lens but is apparently the most important deposit in that area. It is in two benches separated by only 2 feet of micaceous shale but the composition is very different. The

	Water.	Ash.	Volatile.	Fixed Carbon.
Upper bench.....	11.67	9.65	38.6	61.3
Lower bench.....	5.35	20.27	12.8	87.1

lower bench is anthracitic and the upper bench is a high-grade bituminous. The sulphur in both is at most little more than a half of one per cent. The ash is very much higher at most of the North Carolina localities, occasionally reaching 39 per cent. in "best coal."

It may be well to gather the notes respecting ash as presented in the several analyses. The conclusions at best can be merely tentative because analyses, in almost all cases, appear to have been those of hand specimens supposed to represent the average of the seam as shipped: and there are comparatively few showing the composition of coals not regarded as fit for working. It is sufficiently clear that conditions were not the same in all portions of the area occupied by any seam or during the time of its accumulation.

In the Jurassic region of Austria, the coal of one seam near Bernreuth, though externally resembling good coal, has 42 per cent.; near Gresten, the same seam has only 3.9 per cent. The ash is low at Hinterholtz but at Grossau it rises to 10 per cent. At Pechgraben the average of all analyses is 17. These in all cases are from coals which are mined. No attention was paid to other seams because they are "dirty." Similar conditions exist in the Triassic region of Austria. Near Kleinzell, the highest seam has 14 per cent.; near Lilienfeld, the good coal, with little more than 7 of ash, is in the middle seam; near Kirchberg, the coal mined has from

15.8 to 19.9 of ash; but near Rehgarten, the same beds yield a coal, with only 7.8 per cent. of ash; at Loichgraben, the lower seam has good coal, while that from the upper seam, though in appearance equally good, has 52 per cent. Coal is mined near Gossburg, which contains upwards of 30 per cent. of ash. Rachoy has shown clearly that in both Jura and Trias a seam varies greatly in this respect in different portions of its area.

There are numerous coal seams in the Steierdorf-Anina area of Hungary, but only 5 of them are workable—each of these in limited spaces. They are divided into benches, some containing good coal, the others worthless. Samples of good coal from the highest two have from 1.28 to 7.26 of ash, while those from the third have from 2.56 to 16.78. The fourth seam shows less variation, the percentage being 3.44 to 5.65. Within the Fünfkirchen region, 174 seams were crossed by the tunnel at Vasas, with a total thickness of 52 meters. Thirty-nine of them, 14 meters thick, are “dirty” and worthless; of the 28 seams, which are workable in areas, large or small, at least one third become at times too impure to be mined. Hantken gives 26 analyses; 5 show between 16 and 20; 7, from 12 to 15; 4, from 10 to 12 and only 5 have less than 6 per cent. of ash. All of these are from mines in full operation.

The brown coal of the Tchoulym field in Siberia has at most only 2.28 of ash in the samples analyzed but, apparently, the same horizons in the North Tchoulym area yield coal with more than 30 per cent.

The Ipswich seams of Queensland have from 19 to 31 per cent. of ash, while the Burrum coals are all remarkably free from mineral matter, the highest percentage being only 8.

The analyses of specimens from the two benches of a coal seam in the Dan River district of North Carolina show 9.65 in the upper bench and 20.27 in the lower. The best coal in the area has only 5 to 6 per cent., but other samples of “best coal” contain from 20 to 39 per cent. Samples taken by the early students in the Richmond basin were all from the mines then in operation. The lower division of the great seam is usually described as much inferior to the higher portions. In most cases, the samples appear to have been chosen from the better portions, for the ash rarely exceeds

5 per cent.; but in two mines the samples represent different parts of the great seam and the contrast in conditions is marked; at one mine, the ash content in the several parts is, ascending, 10.82, 5.10 and 9.52; in another, the percentages are 5.20, 22.20, 9.80 and 22.60.

There is little of detailed information respecting variations of coal in different portions of lenses, as analyses have been made only of coals supposed to be worth mining. But incidental references abound, which show that, toward the borders, ash increases until the coal becomes worthless.

SUMMARY.

The areas of Jura and Trias, containing coal in economic quantity, are utterly insignificant, when compared with those in which the systems are exposed; but there are many localities in which coal accumulated during brief periods and amid unfavorable conditions. The oölite coals of Britain and a few spots on the continent of Europe are of inferior quality, merely local and almost without interest. Elsewhere the useful deposits are in the lower part of the Lias and in the highest divisions of the Trias. The Jurassic above the Lias and the Triassic below the Keuper may be regarded as barren.

The associated rocks are as in the later periods. The Oölite coals of England are intercalated in sands; the Jurassic coal of Spitzbergen is confined to the Middle or sandstone division, as defined by Nathorst; the Grestener or coal-bearing Lias of Austria is composed of sandstones and clays; the same conditions prevail in the Liassic coal areas of Hungary and Siberia; the Jura-Trias of Queensland and New South Wales are almost wholly sandstone; the upper Trias in Austria and Hungary is sandstone with intercalated shale. But the Jura in Alaska is almost wholly shale and the Upper Trias in some small areas has little sandstone. Freshwater fossils, in rocks associated with coal seams, have been observed in England, Siberia, Spitzbergen, France and Queensland. The structure of the rocks is evidence of, at most, shallow water and in some cases it is very suggestive of eolian agency. False bedding is reported from England, Australia, Germany and North Carolina and ripple marks

are common features at many places. Sandstones and shales frequently contain logs of wood, in such relations as to leave little room for doubt that they are simply stranded material.

There is, however, ample proof that the sea invaded many places where coal was accumulating. The Lower Oölite of England has beds with great abundance of fragmentary marine shells; the Liassic sandstone of Austria and Hungary includes layers with many marine mollusks of littoral types; *Ammonites* was found at one locality, but that does not militate against the conclusion that the water was shallow—if the shell be not drifted, it shows that the genus could exist in shallow water; the Rhætic of Sweden is freshwater below, but has marine shells in the upper portion, where the coal seams are very thin and impure. The lower beds of the Jura-Trias in Queensland have yielded a few specimens of offshore mollusks. The incidental references to beds with marine fossils do not enable one to determine the extent of areas covered at one time or another by salt or brackish water; but in the Fünfkirchen district of Hungary such beds, though few in number, are present in the roof, floor or even partings of several coal seams, recalling the conditions observed in southwestern Utah, within the Benton, near base of the Upper Cretaceous, where a coal seam between beds of marine limestone has freshwater mollusks in a parting. In any event, these deposits suggest that the areas in which they exist were lowland, close to the ocean level. The shallowness of the water cover during their deposition is so evident that one may well conceive that the invasions were due to diversions of drainage, to shifting of channels of large streams. How readily such shifting of channel ways may change conditions in a plain country is shown by Featherstonhaugh's⁴⁹ statement that, in one area, the Arkansas River broke through its banks and converted 30,000 acres into swamp land, killing all the trees. Still more remarkable illustrations exist on the broad plains bordering the Paraguay and other rivers in South America. Many times in sections of coal-bearing rocks, marine deposits are in contact with those of land origin or are separated from them by an inch or two of fine sediment.

⁴⁹ G. W. Featherstonhaugh, "Geological Report of Examination of the Elevated Country between Missouri and Red Rivers," Washington, 1835, p. 84.

The lenticular form of coal seams is as distinct in the Jura and Trias as it is in later periods. It is characteristic of Jurassic coals in Great Britain, France, Austria, Hungary, Siberia and Queensland, as well as of Triassic coals in France, Austria and the United States. Direct reference to this feature is not made in some of the earlier reports as, at the time the studies were made, the bearing which the form of coal seams has upon the problem of their origin was not recognized. But in every area the varying thickness of coal seams is emphasized; the frequent passage of coal into carbonaceous shale is noted; the presence of coal seams in some vertical sections and their absence from others attracted the attention of all observers. The lenses may have considerable area but often they are small; they may be thick or thin. Those of the Tchoulym field of Siberia have small superficial extent, rarely exceeding a few square kilometers and they are rarely connected, but their thickness is so great that the Russian geologists speak of the total quantity of coal in this district as "colossal."

References to contemporary erosion are rare in the reports. Wilkinson has recorded instances of filled channel ways in the Triassic of New South Wales and Hertle has described an interesting "horseback" in a Triassic seam near Rehgarten in Austria. The irregularities in the roof of coal seams in the Richmond field, as described by several observers, have much resemblance to "horsebacks," but the mines in which they were seen were abandoned half a century ago, so that one cannot determine whether or not these irregularities are due to trenching of the coal seams.

Soils of vegetation have been reported from England and the United States, but, if they be present elsewhere as one should think probable, observers have failed to make note of them. In such soils one finds vertical stems of plants, rooted apparently in place of growth but not associated with seams of coal. The Purbeck "dirt beds" of southern England have stumps of conifers and cycads rooted in carbonaceous clay. Mantell states that the conifer stems have lost their bark and have a weatherbeaten surface like that of posts set between tides. They resemble the stumps exposed above the Yahtse gravels, as described by Russell. Stems of the Purbeck conifers were snapped off at 3 or 4 feet from the ground

and they lie prostrate in intervals between the rooted stumps. Henslow saw, at the Portland locality, root-shaped cavities descending into the rock underlying the dirt bed. Equisetiform plants in vertical position and rooted in place of growth occur at several horizons in the Lower Oölite and the Lias in Yorkshire. *Calamites* and *Equisetum*, in erect position, are found in beds above and below seams of coal at numerous localities within the Richmond field. These ancient soils, with erect stems in place, would seem to indicate land surfaces at various times during deposition of the coal-bearing deposits.

As in the newer formations, the roof may be sandstone, shale or limestone; it may contain marine or freshwater forms. At Brora in Scotland, it is a mass of marine shells with quartz sand and carbonaceous materials, bound together by a calcareous cement; it passes downward into coarse coal—a faux-toit. Marine shells are present in the roof of at least one seam in the Fünfkirchen district and bituminous limestone rests on the coal at some localities near St. Anton in Austria. The ordinary roof is sandstone or shale, one or the other predominating in different areas; not infrequently it is sandstone in one mine but shale in another nearby. Finely laminated sandstone is not rare. Roof shales are often very rich in plant remains, leaves being especially well-preserved, as though they had been lifted gently from the surface of the bog by muddy water. The sandstone roof of the Lettenkohle in Unterfranken is an old soil, containing erect roots.

Frequently, the passage from good coal to roof is gradual and this is equally true of the passage from coal to the floor, there being distinct faux-toit and faux-mur; but, at times, the passage is abrupt. Occasionally, the character of the coal changes in such manner as to suggest that one portion of the seam sank below drainage while the other remained above it; the "Kimmeridge coal" in the typical area is merely a rich carbonaceous shale, whereas in Wiltshire it resembles peat. In the Tchoulym field of Russia, the burial must have been abrupt, for the upper portion of the coal is very peat-like at some localities. Coal seams, more than 2 feet thick, are rarely single, but are divided into benches by partings of sandstone or clay, often containing much mineral charcoal. These vary much

in thickness. The interval between seams XI. and XII. in the Fünfkirchen area is from zero to 72 feet; similar, though less marked variations are recorded from other localities. Ordinarily, the partings appear to be of freshwater origin, but occasionally one contains marine forms of immediately offshore types. The character of the coal differs greatly, many times, in the several benches; some yield excellent coal, but that from others is worthless; that from one bench may be caking, that from another may be non-caking; that from one bench may be richly bituminous while that from another may be almost anthracitic. Coal of Jurassic and Triassic age is usually so far advanced in chemical change that identifiable plant structure seldom appears in the coal itself until after treatment with Schultze's solution. But Grand'Eury states that, at Nice, *Equisetites* is present in the coal, recognized by its form, though all trace of structure had disappeared. The Keuper coals of the Vosges contain bark and seeds, while Rhætic coal from Bayreuth has many streaks which appear to consist wholly of pollen exines. In the Rhætic of the Richmond field *Equisetum* is abundant in coarse coal. But treatment with Schultze's solution brings out evidence of vegetable tissue from all the coals examined.

The floor is as variable as the roof, being clay, shale or sandstone. Limestone is reported from only two localities described in works consulted by the writer. Within several counties of England the floor of the Lower Oölite coal or coaly shale is usually clay or fine-grained more or less clayey sandstone and it contains many roots, which, in at least one locality, clearly descend from the overlying coaly shale. A calcareous floor in the Causses of France holds roots, which are well defined. Lipold and his associates give no details respecting the floors of Austrian coal seams but the presence of plant remains is recorded incidentally for many localities. The presence of roots in floors is a familiar phenomenon in the Lias of Hungary; in the Steierdorf-Anina district, they are described as vertical, often branching, and they are associated with plants of several types. According to Grand'Eury, roots, both woody and herbaceous, are abundant in underclays and partings. The condition is similar in the Fünfkirchen area, where, according to Gothan, the underclay proved to be a root-bed in every locality

at which the floor could be studied. *Vertebraria* has been recognized in underclays of Queensland; *Equisetites* roots are in underclays of the Vosges as also at Nice, where the plants seem to have supplied material for the coal. The underclays of Lettenkohle in Unterfranken are root-beds. The coals of the Richmond field, according to Rogers, have nothing answering to the *Stigmaria*-clays of the Carboniferous; but the underclays are present. They carry no *Stigmaria*, for the gigantic *Lepidodendron* and *Sigillaria* had disappeared; but Fontaine has shown that *Schizoneura* is present in the floor of the main bed.

The flora has been studied in all of the important areas. In the Upper Oölite of southern England, ferns, conifers and cycads are the prevailing types; the Lower Oölite of Yorkshire contains ferns as the preëminent feature though conifers and cycads are abundant; *Equisetum* is common above the coal horizon, at which ferns and conifers prevail. Conifers, cycads and some ferns from Spitzbergen have been described by Nathorst. The Ipswich or upper division of the Queensland Jura-Trias has 11 species of ferns, 4 of cycads and one of *Equisetum*; ferns prevail in the lower portion of the Lias within the Steierdorf-Anina area and cycads in the upper; but in the Fünfkirchen area, the flora consists chiefly of ferns, cycads and lycopods. *Equisetum* is extremely abundant in the Trias of Austria and *Calamites* and *Pterophyllum* were obtained at many places; the Trias of Hungary has yielded cycads, *Palissya* and some ferns, but collections have been small, as the coal is unimportant. The beds in the Atlantic coast areas of the United States contain cycads, reeds and ferns—the last being few in species but extremely abundant in individuals.

That the coal-bearing deposits were laid down on an undulating surface is well shown in the Liassic areas of Hungary. Within the Törzburg area, the underlying rock is crystalline schist; in the Steierdorf area it is Dyas but in that of Fünfkirchen it is Trias. A similar condition is distinct in the Trias of Virginia and North Carolina. In the Richmond field, the interval between the lowest coal seam and the granite varies from a few inches to 600 feet, while in the Dan River basin of North Carolina it is more than 1,000 feet.